

# ANALYSIS OF RESIDUAL STRESSES ON THE TRANSVERSE BEAM OF A CASTING STAND BY MEANS OF DRILLING METHOD

Received – Prispjelo: 2014-01-31

Accepted – Prihvaćeno: 2014-05-25

Original Scientific Paper – Izvorni znanstveni rad

The presented paper demonstrates the application of drilling method in the analysis of residual stresses on the transverse beam of a casting stand. In the initial stage of the analysis the determination of strains was done for individual steps of drilling in the area which was determined by means of numerical analysis. The drilling was carried out gradually by 0,5 mm up to the depth of 5 mm, while the diameter of the drilled hole was 3,2 mm. During the analysis we used the drilling device RS-200, strain indicator P3 and SGD 1-RY21-3/120. The paper presents the development of residual stresses throughout the depth of the drilled hole which were determined according to standard ASTM E837-01, by means of integral method, power series method and by means of Power Series method.

**Key words:** residual stress, casting stand, drilling method, SGD 1-RY21-3/120

## INTRODUCTION

Residual stresses are stresses which occur in the material of an object without the object being loaded by external forces. Residual stresses appear in almost all technological processes during the production of components or structures. In some cases, residual stresses occur during the operation of the structure, during assembly works or possible overloads, during repairs or the re-assembly of the structure. This topic is the subject of a great number of works, such as [1-4], considering the fact that residual stresses can have a positive or a negative effect. This effect depends on magnitude, symbol and distribution of stress in relation to stresses caused by external loads. The negative residual stresses are unwanted and their removal is costly. Good knowledge hereof is, though, very important for determination of real stress state of an object during operation.

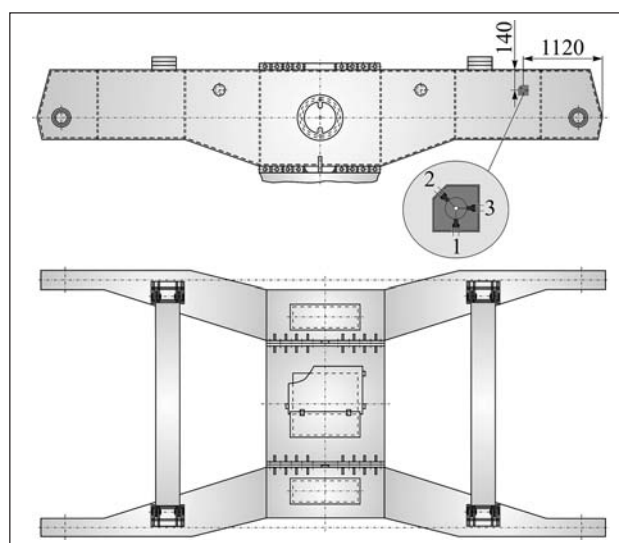
Despite the progress in numerical methods, the determination of residual stresses is still considered the domain of experimental methods. One of the most common methods of quantitative determination of residual stresses is the drilling method which belongs to the group of semi-destructive methods. The principle lies in determination of the change of stress state or stress which occurs while a hole is being drilled into the object in question, i.e. the object in which residual stresses occur. The change of strain is usually determined with strain gauge sensors. With magnitudes and directions of released strains, dimensions of the drilled-out hole, and material features known it is possible to determine residual stress on the basis of analytical or experimental analysis. In the presented article residual stresses are

determined according to standard ASTM E837-01, by means of integral method Power Series [4, 5].

## EXPERIMENTAL PART

For the measurement of released strains after the hole had been drilled into the transverse beam of the casting stand we used a strain gauge sensor 1-RY21-3/120. The orientation of the main directions hereof is depicted in Figure 1.

The schematic drawing of the transverse beam of the casting stand and the place of application of the strain gauge sensor in the area of plastic deformation are shown in Figure 1.



**Figure 1** Schematic drawing of the transverse beam of the casting stand with the place of strain gauge sensor's application

The drilling was done step by step with the increment of 0,5 mm up to the depth of 5 mm. The diameter of the drilled-out hole was 3,2 mm. After each drilling step, values of measured strains released by the drilling were read. Table 1 includes measured strains which were released after individual drilling steps [6]. The column 1 lists values marked as  $\varepsilon_a$ , the column 2 includes values for  $\varepsilon_b$  and the column 3 includes values for  $\varepsilon_c$  (Figure 1).

Table 1 Measured strains at individual drilling steps

Depth / mm	$\varepsilon_a / 10^{-6}$	$\varepsilon_b / 10^{-6}$	$\varepsilon_c / 10^{-6}$
0,50	-12,00	-11,00	-12,00
1,00	-26,00	-16,00	-23,00
1,50	-40,00	-15,00	-28,00
2,00	-69,00	-6,00	-38,00
2,50	-103,00	5,00	-47,00
3,00	-103,00	5,00	-47,00
3,50	-103,00	5,00	-48,00
4,00	-119,00	10,00	-53,00
4,50	-145,00	8,00	-62,00
5,00	-157,00	7,00	-70,00

Figure 2 depicts graphical interpretation of distribution of interpolated strain values, distributions of measured strain values and deviation angles of the sensor 1 from the main direction.

Figure 3 depicts distributions of residual stresses in individual drilling steps, calculated values of maximum residual stresses and deviation angle from the axis of the sensor 1.

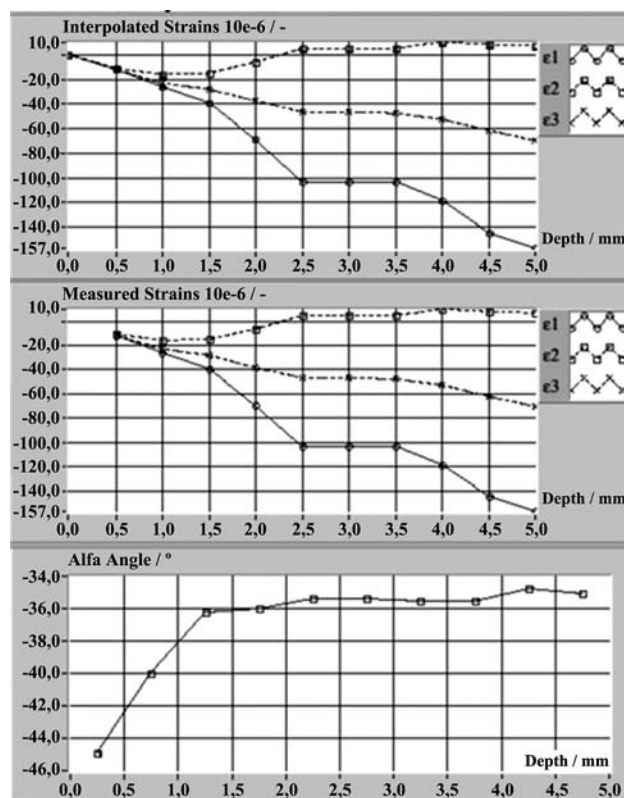


Figure 2 Distributions of interpolated strains, measured strains and deviation angles of the sensor 1

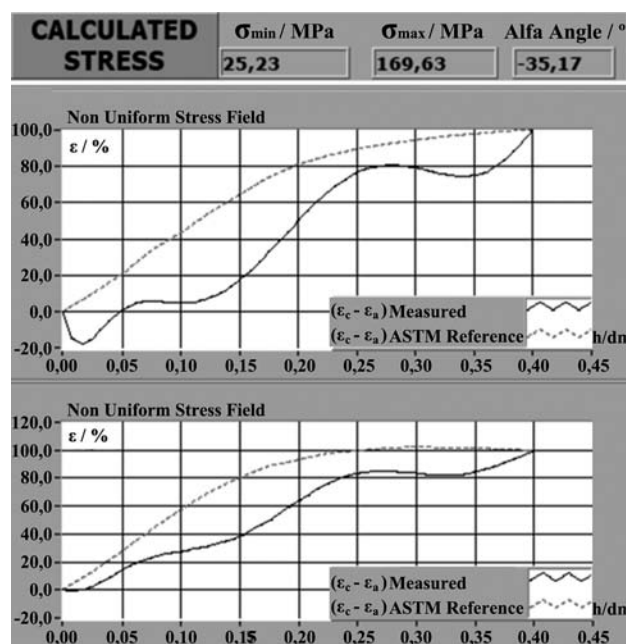


Figure 3 Graphical presentation of residual stresses in individual drilling steps

These values of residual stresses were determined according to standard ASTM E837-01. This applies to equal distribution of residual stresses throughout the depth of the drilled hole.

In the analysis of residual stresses in the area under analysis we used determination procedures related to uneven distribution throughout the depth of the drilled hole. For the purposes of this calculation was used the Integral method and the Power Series method.

Listed in Table 2 are the interpolated and calculated values of strains and residual stresses via integral method [6].

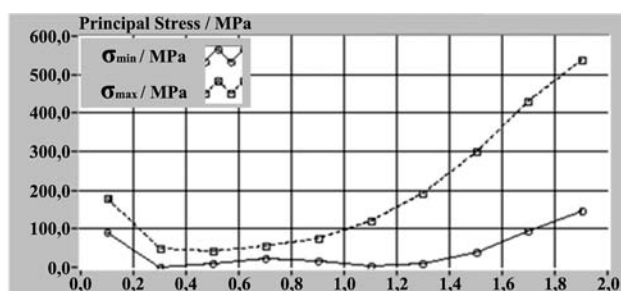
Table 2 Interpolated and calculated values of strains and stresses by means of integral method

Depth / mm	$\varepsilon_a / 10^{-6}$	$\varepsilon_b / 10^{-6}$	$\varepsilon_c / 10^{-6}$	$\alpha / ^\circ$	$\sigma_{min} / \text{MPa}$	$\sigma_{max} / \text{MPa}$
0,10	-7,95	-3,90	-7,21	-42,12	89,96	180,49
0,30	-12,27	-8,55	-9,94	-32,69	0,02	47,54
0,50	-14,96	-12,70	-14,46	-41,44	10,78	41,64
0,70	-17,86	-15,61	-19,40	-52,16	24,16	53,89
0,90	-22,23	-16,95	-23,00	-46,93	15,63	74,17
1,10	-28,76	-16,70	-25,14	-39,98	4,52	120,68
1,30	-37,55	-15,07	-26,89	-36,37	8,23	192,78
1,50	-48,22	-12,37	-29,43	-35,23	37,85	299,03
1,70	-60,02	-9,02	-33,27	-35,21	95,19	430,98
1,90	-71,99	-5,42	-37,98	-35,53	145,75	538,96

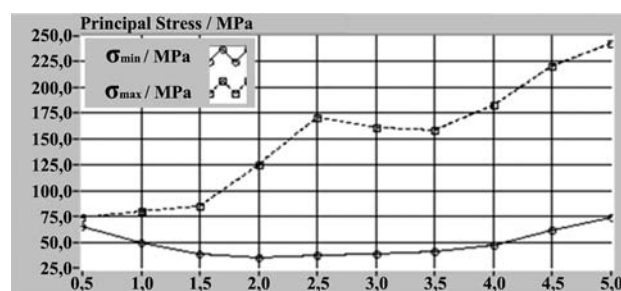
The distribution of residual stresses, which was specified by means of integral method, is depicted in Figure 4.

The interpolated values of strains and the values of residual stresses determined by the Power Series method are listed in Table 3 [6].

The distribution of residual stresses determined by the Power Series method for individual drilling steps is depicted in Figure 5.



**Figure 4** Distribution of residual stresses determined by integral method



**Figure 5** Distribution of residual stresses determined by means of Power Series method

**Table 3** Interpolated and calculated strain and stress values by means of Power Series method

Depth / mm	$\varepsilon_a / 10^{-6}$	$\varepsilon_b / 10^{-6}$	$\varepsilon_c / 10^{-6}$	$\alpha / ^\circ$	$\sigma_{min} / \text{MPa}$	$\sigma_{max} / \text{MPa}$
0,50	-12,01	-11,00	-12,00	-44,94	65,92	73,53
1,00	-25,98	-16,01	-23,00	-40,01	49,47	80,51
1,50	-40,06	-14,98	-28,01	-36,23	38,67	85,18
2,00	-68,91	-6,03	-37,98	-35,97	35,33	125,83
2,50	-103,11	5,03	-47,02	-35,35	36,68	170,11
3,00	-102,91	4,98	-46,98	-35,36	38,52	160,99
3,50	-103,05	5,01	-48,01	-35,57	41,36	158,74
4,00	-118,98	10,00	-53,00	-35,52	46,56	183,08
4,50	-145,00	8,00	-62,00	-34,79	62,02	220,33
5,00	-157,00	7,00	-70,00	-35,08	73,40	243,13

## RESULT AND DISCUSSION

Considering the experimental analysis of residual stresses on the casing stand transverse beam we can draw the conclusion that the value of residual stress determined according to standard ASTM E837-01 reaches up to 170 MPa. Values of residual stresses determined both by means of integral method and Power Series method reach up to the yield point values in the surface area and cause plastic deformations that has significant effect on fatigue strength and life. Measurements in the given point prove that residual stress is of tensile nature, which, from the viewpoint of crack spreading, is the most dangerous scenario. This stress combines with stresses resulting from operation loads. Considering the gained results, it is obvious that such high values of residual stresses may have considerable effect on life of the bearing structure [7, 8]. From the above-mentioned reasons, when proposing measures for the prolongation of life, it is necessary to take residual stresses into consideration [9, 10].

## CONCLUSION

Since the values of residual stresses are not defined in analytical and numerical calculations, no conclusions on the occurrence of local failures can be drawn from the stress analysis of structural parts. There is a real failure and residual stresses prove possible causes of its occurrence. The magnitude of residual stresses should al-

ways be considered when evaluating the life of structural elements as well as when proposing its prolongation.

## Acknowledgement

This research was supported by grant project VEGA No. 1/0937/12, VEGA No. 1/0102/11 and project FGV/2013/5.

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**Note:** English language: Mgr. Ján Želonka, Faculty of Arts, Constantine the Philosopher University in Nitra, Department of Translation Studies, Slovakia